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(54) **Artificial onlay tooth crowns and inlays.**

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**WO 87/06451, EP-A-0 225 279, EP-A-0 384 907 (Art. 54(3)(4) EPC), Hawley's Condensed Chemical Dictionary**

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## Description

### BACKGROUND OF THE INVENTION

This invention relates to accurately shaped artificial all ceramic onlay tooth crowns and inlays as replacement for lost tooth structure. By starting from a negative reproduction of the prepared tooth and from this copy mill the surface which will fit into the prepared cavity, a tooth crown or an inlay is obtained which is easier to produce and to lower cost. In addition, the onlay crown and inlay has higher strength and a more accurate shape. Preferably the coping is manufactured from a biocompatible, high strength, ceramic material, which is sintered to high density.

Artificial tooth crowns and inlays made from a metal are today manufactured mainly in the following way: A dentist makes a preparation on a tooth, on which a dental construction is to be fixed in the mouth of a patient, an impression is made and with this impression a copy of the preparation is made in gypsum. On this model a dental technician prepares a crown in wax. The adjacent teeth must be considered, and the dental technician must have models from the two jaws. A sprue former in wax is fixed on one of the cusps of the wax crown. The wax crown is loosened from the gypsum model. The wax crown with the sprueformer are invested in a metal ring with investment. The wax is burnt out and a crown can be cast in a precious or non-precious metal. The cast crown can in certain cases be covered by a veneer made of porcelain in order to obtain a colour of the tooth crown similar to the colour of natural teeth. Instead of porcelain plastic material can be used.

The fabrication of tooth crowns in glass is very close to the technique described above with the difference that after the casting a thin layer of porcelain is painted on the surface and fired, in order to give the tooth crown individual tooth colours.

Tooth crowns fabricated mainly of porcelain can be made with conventional dental porcelain technique on a sheet made of a precious alloy. Porcelain crowns and inlays can also be made with conventional dental porcelain technique on a model of the abutment. The material in this model has no changes in dimension on heating up to 1200°C. When the tooth crown or the inlay is ready the model of the abutment is removed by sand blasting.

The above described complicated and time consuming methods are used to manufacture crowns and inlays, which will fit in individually prepared cavities in natural teeth.

The problem with the material now used (porcelain, glass etc) in artificial tooth crowns is their brittleness, which often gives early fracture, and these artificial crowns and inlays must be replaced more or less regularly.

WO 87/06451 relates to a method and an arrangement for the production of insert bodies for the artificial rebuilding of teeth and human limbs etc. The document discloses the use of tools for machining blanks copying the external contours of a replica (copy milling).

EP-A-0 384 907 (published on 29.08.90) is an earlier European Application with priority date of 23/02/89, and which is only to be considered under Art. 54(3)(4) EPC for the purpose of novelty, relates to a further development of the method discussed in WO 87/06451. The document discloses the application on ceramic tooth crowns, at which compensation of the shrinkage during the sintering of the ceramic material can be performed in the copy milling operation.

EP-A-0 225 279 relates to micaceous-corderite-glass ceramic material and their use in tooth crowns etc. The main method of preparing the products is the lost wax method followed by casting.

### OBJECTS AND SUMMARY OF THE INVENTION

One object of the present invention is to provide artificial tooth crowns and inlays, which are easier and accordingly cheaper to make and, in addition, have higher strength and accuracy to shape.

Another purpose is to make an inlay or an onlay tooth crown by using densely sintered, high strength ceramic material, provided that the demand of high strength, accuracy to shape (that means compensate for the shrinkage during sintering) can be combined with the demand on the application of porcelain concerning burning, adherence, biocompatibility and esthetics.

### BRIEF DESCRIPTION OF THE DRAWINGS

Fig 1 is a natural tooth with an artificial inlay (dotted). This figure explains which cross sections are shown by Fig.2 and Fig.3

Fig.2 is a cross section of a natural tooth with an inlay

Fig.3 is a cross section of a root filled natural tooth with an inlay.

Fig.4 is a natural tooth with an onlay tooth crown (dotted). This figure explains which cross sections are

shown by Fig.5 and Fig 6.

Fig.5 is a cross section of anatural tooth with an onlay tooth crown.

Fig.6 is a cross section of a root filled tooth.with an onlay tooth crown.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Fig.1 shows an inlay in a tooth. In the figure the border between the cavity and the inlay is indicated as I, the axis of the tooth as X.

Fig.2 shows a cross section of an inlay in a natural tooth. In the figure,the veneer is indicated as A, the core made from dense sintered ceramic as B, the cement as C, the copy milled surface of the core as D, the prepared surface of cavity as E, the pulp as F, and the natural tooth root as H.

Fig.3 shows a cross section of an alternative design for a root filled tooth, the same letters mean the same things as with Fig 2, while a root filling is indicated with G.

Fig.5 shows a cross section of an onlay tooth crown on a natural tooth, and

Fig.6 shows a cross section of an alternative design for an onlay tooth crown for a root filled tooth, the same letters mean the same things as with Fig 2 and Fig.3.

In each of the Figures, the artificial onlay tooth crown or the inlay are the combination of the core B with the veneer A. They are fixed in the prepared cavity E with cement C.

According to the present invention, artificial onlay tooth crowns and inlays are made in which the core is prefabricated from a biocompatible material with part of the outer surface of the core D given such dimensions as to fit into a preparation E, which can be a preparation for an inlay or a preparation for an onlay tooth crown or a preparation for a tooth crown on a root canal pin. A biocompatible material for the core is a material which is not toxic and does not cause damage on oral tissues or does not give unwanted system effects. In addition this material must not give any discolourations or otherwise give unwanted effects to the veneer material. The onlay tooth crowns and the inlays are fixed by cementation in the cavities.

The present invention allows a considerable simplification of the handicraft of the dental technician. With the aid of gypsum models of the two jaws and with the prefabricated core placed on the model of the tooth preparation a dental technician can make the final design of the onlay tooth crown or inlay and at the same time control their function and size. In order to make the veneer, a porcelain furnace or an apparatus for pressing of composite veneer is needed. The method of making a tooth crown or an inlay to fit into an existing preparation according to the present invention decreases essentially the time of production for these constructions and at the same time the strength and precision regarding the accuracy to shape increase.

Cores according to the invention can be made of ceramic by copy milling the negative reproduction from the prepared cavities (E). This copy milling gives the boundary surface of the onlay tooth crown or of the inlay to the cavity (D). A negative reproduction is made by making an impression of the prepared tooth or a model from this tooth together with its adjacent teeth. The impression material fills up the whole cavity and when the impression is removed from the teeth, this impression comprisess the surface D and the contact points to the adjacent teeth. From the impression material closest to surface D is adjusted in order to have this surface D within reach for copy milling. The contacts with the adjacent teeth give the limitation in mesial distal direction. The contour outside the cavity is prepared manually with conventional dental technical machining practice. A negative reproduction can be e.g. a Kerr impression, or a silicon impression.

The core according to the invention is made from a biocompatible densely sintered, high strength ceramic material. On the core obtained the veneer is built up, so that the final product will be a tooth crown or an inlay fitting into existing preparation and to the actual whole set of teeth.

As can be seen from Fig. 2 and Fig.3 artificial inlays are made as a core in densely sintered ceramic (B) with veneer (A). They are fixed in the prepared cavity by e.g. cementing. The thin layer of cement (C) connects the prepared cavity walls (E) with that part of the surface of the inlay or the onlay tooth crown, which has been made so that this surface (D) fits with great precision into the prepared cavity (E). The layer of cement can have a thickness < 200µm preferably 25-75 µm. Artificial onlay tooth crowns are made as a core in densely sintered ceramic (B) with veneer (A). As can be seen from Fig. 6 the preparation of a root filled tooth is extended down into the root canals in order to have optimum retention of the tooth crown. The veneer (A) can be made from dental porcelain or plastic. The cementing of the constructions can be made with e.g. glassionomercement, phosphatcement, or some resin can be used. In the last case it can be an advantage to silane treat the surfaces (D) of the constructions which will be joined with the prepared surfaces of the tooth structure. The enamel walls of the prepared cavity can be etched and the dentin walls of the prepared caviy can be treated with dentine adhesive (E) before the above described restorations are cemented with resin, which could comprise fillerparticles of e.g.ceramic or polymer material. The preparation of the cavity is made without undercut. Undercuts can be blocked with some cement e.g. glassionomercement.

The ceramic powder can be made by several well known methods. Traditional powder metallurgical techniques can be used, where the different components are mixed and ground under dry or wet conditions with water or an inorganic solvent (e.g.alcohols) as grinding liquid. So called SOL-GEL technique can also be used where different oxide materials are deposited together from a water solution or are co precipitated from metal alcoxides in e.g. water free alcohol by controlled addition of water. A combination of different techniques can also be used by using SOL-GEL technique to deposit a surface layer of desired metal oxide on a powder material. Lubricants or other organic binders depending on the choice of forming method may be added to the ceramic powder when needed at suitable times in the process as is conventionally known. Other preparation routes of the ceramic material are also possible such as reaction sintering where a suitable metal is oxidized, nitrided etc. For example, aluminium can be oxidized under carefully controlled processing to alumina. These methods allow preforming or reinforcement by fibres, e.g., in a felt infiltrated with liquid metal.

Many of the monolithic ceramics which are biocompatible may have a brittle performance if they are not sintered to nearly full density, more than 98% and preferably > 99.5% of the theoretical density. However, these ceramics can be strengthened by a number of toughening mechanisms. Finely dispersed particles, platelets, whiskers or fibers raise the fracture toughness of the composite. Typical additives are the nitrides, carbides, borides or mixtures thereof of the transition metal of group IV-VI or of the elements Al or Si. Toughening may also be achieved by so called transformation toughening, i.e., additions of unstabilized $ZrO_2$ or $ZrO_2$ stabilized with $Y_2O_3$, MgO or GaO. The additions of these latter oxides shall not exceed 25 wt%, but should be more than 2 wt%. The best performance is obtained with 3-12 wt% of the $ZrO_2$.

The powder with lubricants and/or other organic binders is cold isostatically compacted , uniaxially pressed, slip cast, pressure cast, injection moulded or compacted in another suitable way. The compacted body has such dimensions that it comprises enough material for the copy milling of the outer shape of the core, which will fit into the prepared cavity (E). During this copy milling the sintering shrinkage must be considered. Thus, the copy milled surface (D) must be enlarged so that the compacted body has such dimensions that after the shrinkage during the subsequent sintering process to high density, has desired final geometrical external shape. (D) which will fit into the prepared cavity (E) with great accuracy.

The ceramic body can also be presintered before the copy milling of the surface (D) fitting to the prepared cavity (E). All the other surfaces are prepared near final shape before the final sintering. It is important that the ceramic material is sintered to closed porosity, which for an oxide material means at least 95% of theoretical density, but in order to ensure good mechanical strength the material should preferably have a density over 98%, while densities over 99.5% give the best strength.

The sintering can take place in a vacuum or under hydrogen atmosphere, under normal atmospheric pressure or under increased pressure in connection with the overpressure sintering or hot isostatic compaction or alternatively by hot pressing. Highly pure $Al_2O_3$ becomes translucent during sintering to full density in vacuum or in hydrogen atmosphere, which is an advantage when natural teeth are to be imitated. Pure oxide material can be sintered in air, but some composites have to be sintered in inert or controlled atmosphere. The core is given an external shape so that the building-up of the veneer is facilitated. The external shape can be such that it is roughly similar to natural teeth. After the final sintering the surfaces of the core may need some grinding, especially the external surfaces outside the prepared cavity. This grinding will be made with the inlay or the onlay crown on a model of the prepared tooth. If dental porcelain is used as the veneer with a coefficient of thermal expansion adapted to the material of the core, the porcelain will adhere better. In the case of $Al_2O_3$ as the core material there will be a "chemical bond" between $Al_2O_3$ and porcelain. This means that the external surface of the core does not need any retention elements. When using other veneer materials e.g. plastic, mechanical retention elements can be needed e.g. grooves, pits or on the external surface sintered retention elements or a silane treatment of the surface. The core can also be given such a shape that the ceramic inlay or onlay tooth crown does not need any veneer material. The surfaces of the inlay or the onlay tooth crown which is a part of the external surfaces of the repaired tooth must in this case before the cementing be ground and polished to a surface fineness of 0.5-5μm preferably 0.5-1μm.

The ceramic base material in the core comprises preferably one or several biocompatible oxides (including phosphates, silicates and sulfates), with the additives of carbides, silicides, nitrides or borides with or without binder metal (preferably iron-group metals) in addition to conventional sintering aids. The base material can also comprise other biocompatible high performance ceramics such as nitrides. oxynitrides, carbides, etc. Examples of the two former materials are $Si_3N_4$, $Si_2N_2O$, sialon, AlN, AlON, etc. Examples of biocompatible oxides, which can form base matrix for the ceramic body, are $Al_2O_3$, $TiO_2$, MgO, $ZrO_2$, and $ZrO_2$ (partly or totally stabilized with amounts of up to 25 weight% of $Y_2O_3$, MgO or CaO).

Also, components such as SiC, TiN, TiC, $TiB_2$, $Si_3N_4$, or other biocompatible carbides or nitrides of group IV,V or VI can be present as particles with a size of <25μm preferably <10μm and/or as whiskers (hair shaped single crystals) with a length to diameter ratio >5, preferably >10 and/or fibers (polycrystalline) with a diameter

>10μm and/or as single crystal platelets with an approximate diameter of 5-50 μm preferably 5-20 μm and a thickness of 1-10μm, preferably 1-4 μm. The amount of whiskers, fibers and/or platelets should not exceed 60 volume%, preferably less than 40 volume %..

In a preferred embodiment the ceramic material comprises >50% preferably >85% by weight of $Al_2O_3$ with additives of conventional sintering aids. In order to increase the strength <25weight % preferably 3-12 weight % of $ZrO_2$, and/or 5-40 weight % preferably 10-30 weight % of SiC whiskers can be added. In order to get a suitable colour, coloured components can be chosen. Additives e.g 0.1-10 weight % preferably 0.5-5 weight %, of TiN and/or ZrN will give $Al_2O_3$ based inlays and onlay crowns a faint yellow shade.

The principles, preferred embodiments and modes of operation of the present invention have been described in the foregoing specification. The invention which is intended to be protected herein, however, is not to be constructed as limited to the particular forms disclosed, since these are to be regarded as illustrative rather than restrictive.

The invention is additionally illustrated in connection with the following Example which is to be considered as illustrative of the present invention. It should be understood, however that the invention is not limited to the specific details of the example.

## EXAMPLE

A core to fit a prepared cavity in a molar according to Fig.5 was made from a powder with the approximate composition 99.85 weight % of $Al_2O_3$ and 0.15 weight % MgO. Blocks (15mmx15mmx30 mm) of the powder were uniaxially compacted and presintered at 1200°C. An impression was made of the tooth with the prepared cavity with a putymass of a silicon impression material. This impression contained the negative reproduction (D) of the prepared cavity walls (E). With a scalpel the impression material outside the boundary (I) was carefully removed. From the impression with use of the presintered blocks the surface (D) was copy milled and at the same time enlarged to such a size that it allowed a shrinkage of 16.5% during the sintering. From the boundary (I) the external surface of the core was milled and machined to a minimum thickness of the core of 1.2 mm in the direction of the axes through the tooth. The sintering was performed in air during 2 hours at 1600°C. After the sintering the core had a relative density of 99.5% and a minimum thickness of 1 mm in the direction of the axes through the tooth. An ordinary impression was made from the whole jaw and from this impression a model of the jaw was made i gypsum. The core fitted perfectly into the prepared cavity and commercially available dental porcelain was fired on the surface. The first layer porcelain compriseed about 50% $Al_2O_3$ and was fired at 1150°C during 10 minutes. During the heating the furnace was under vacuum, but when the final firing temperature was reached the firing was performed under atmospheric pressure. The remainder of the crown was fired at 960°C. The dental porcelain combined chemically with the alumina without any gap between the porcelain and the densely sintered core. The onlay crown fitted perfectly on the model of the tooth and was ready to be cemented with conventional methods in the tooth cavity in the mouth of a patient.

## Claims

1. A method of making an artificial onlay tooth crown or inlay for fit into a prepared tooth cavity comprising: forming a negative reproduction of said cavity; copy milling a core from said negative reproduction including a surface abutting said cavity and an external surface; and applying a veneer to at least part of the said external surface of said core,
   **characterized** in that the said core consists of a biocompatible ceramic material with a relative density of > 95 %, and that the ceramic material of the core comprises at least one of the oxides $Al_2O_3$, $TiO_2$, MgO, $ZrO_2$ and $ZrO_2$ with up to 25 weight % of at least one of $Y_2O_3$, MgO and CaO, said copy milling being performed on a compacted or presintered body, after which the body is sintered to said final density.

## Patentansprüche

1. Verfahren zur Herstellung einer künstlichen Zahnkrone oder -füllung zum Einpassen in eine vorbereitete Zahnhöhlung, bei dem man eine negative Reproduktion der Höhlung bildet, einen Kern aus der negativen Reproduktion mit einer an die Höhlung angrenzenden Oberfläche und einer Außenoberfläche kopierfräst und auf wenigstens einem Teil der Außenoberfläche des Kerns eine Überzugsschicht aufbringt, **dadurch gekennzeichnet,** daß der Kern aus einem biologisch verträglichen Keramikmaterial mit einer relativen Dichte >95 % besteht und daß das Keramikmaterial des Kerns wenigstens eines der Oxide $Al_2O_3$, $TiO_2$,

MgO, $ZrO_2$ und ZrO2 mit bis zu 25 Gew.-% wenigstens einer der Verbindungen $V_2O_3$, MgO und CaO umfaßt, wobei das Kopierfräsen mit einem verdichteten oder vorgesinterten Körper durchgeführt wird, wonach der Körper zu seiner Enddichte gesintert wird.

## Revendications

1. Procédé de fabrication d'une couronne dentaire ou d'un inlay destiné à s'ajuster à l'intérieur d'une cavité de dent préparée consistant: à former une reproduction négative de ladite cavité; à faire une copie exacte d'un noyau à partir de ladite reproduction négative comprenant une surface s'appuyant sur ladite cavité et une surface externe; et à appliquer un vernis à au moins une partie de ladite surface externe dudit noyau, caractérisé en ce que ledit noyau est constitué d'une matière céramique biocompatible avec une densité relative supérieure à 95%, et que la matière céramique du noyau comprend au moins un des oxydes $Al_2O_3$, $TiO_2$, MgO, $ZrO_2$ et $ZrO_2$ avec jusqu'à 25 % en poids d'au moins un des oxydes Y203, MgO et CaO, ladite copie exacte étant réalisée sur un corps compacté ou préfritté, après quoi est le corps préfritté à ladite densité finale.

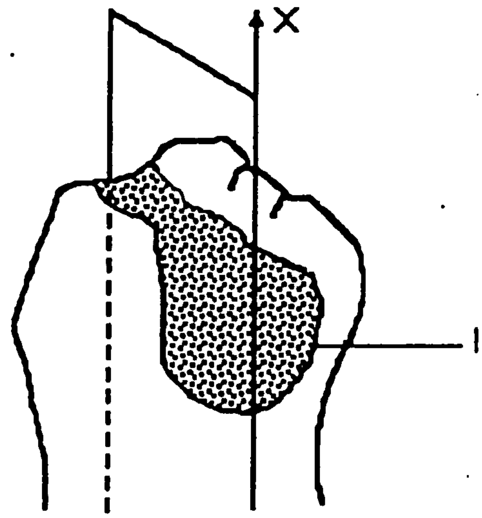


Fig.1

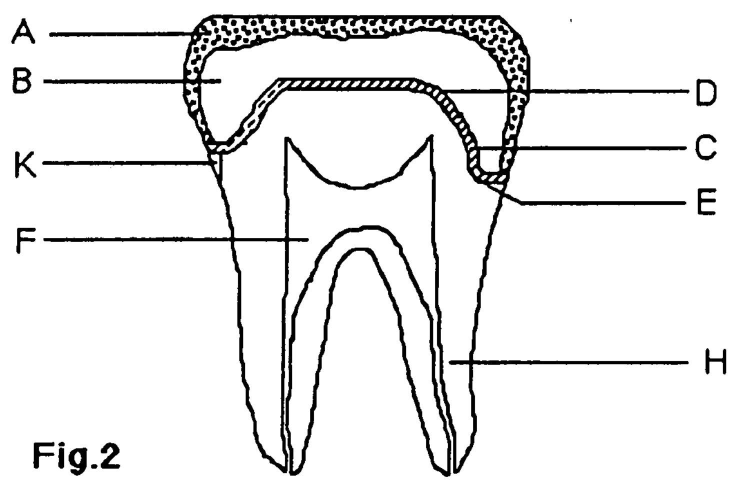


Fig.2

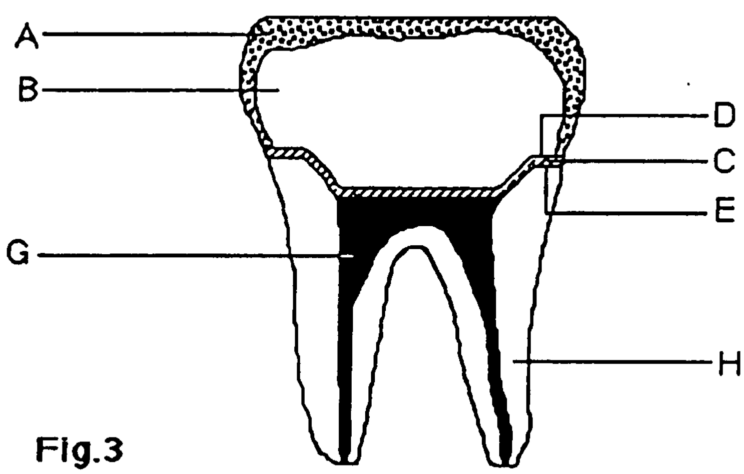


Fig.3

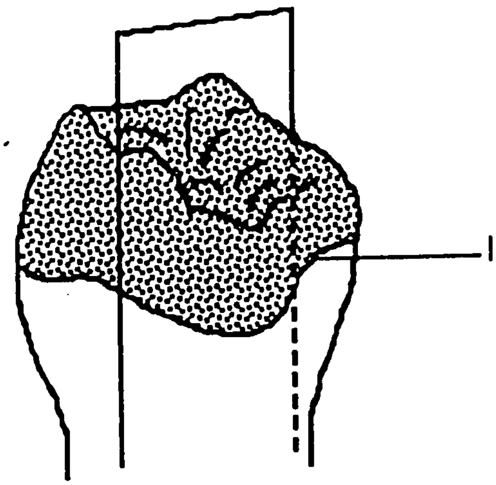


Fig.4

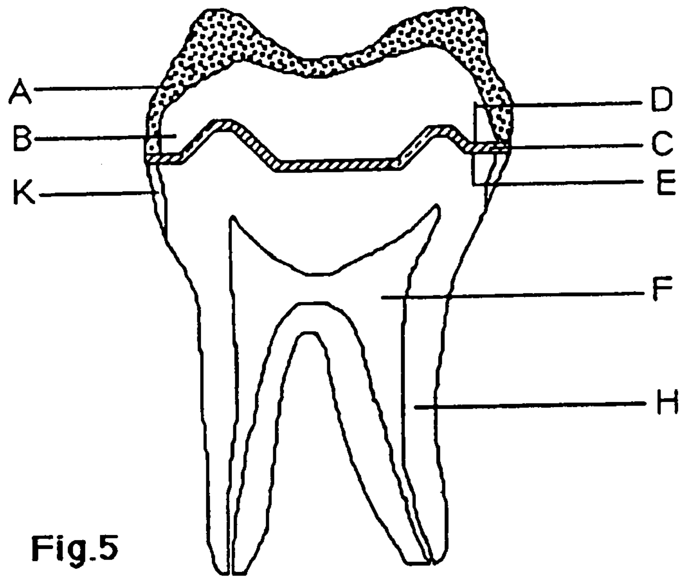


Fig.5

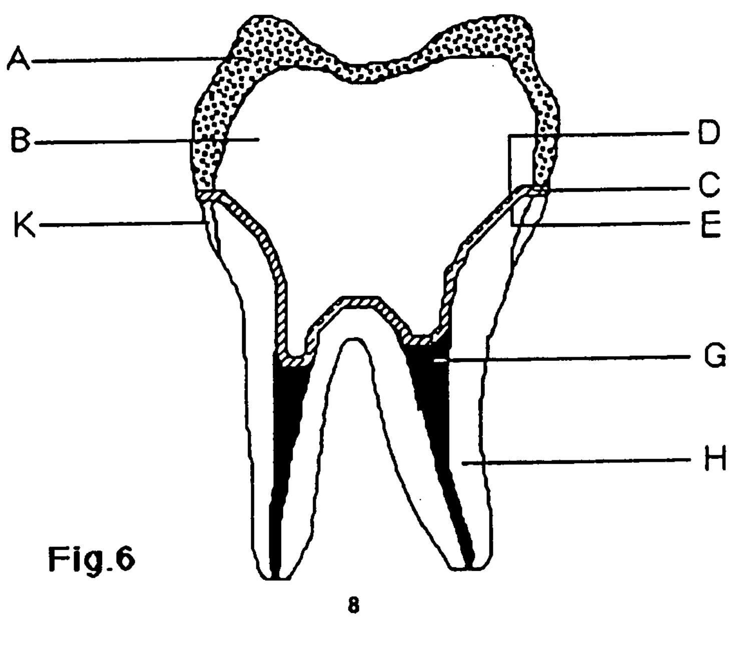


Fig.6